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# FACTORS INFLUENCING PERCENTAGE CALF CROP IN RANGE HERDS

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# FACTORS INFLUENCING PERCENTAGE CALF CROP IN RANGE HERDS

G. H. HART[1] AND H. R. GUILBERT[2]

## IMPORTANCE OF CALF CROP AS SHOWN BY COST OF PRODUCTION STUDIES

Recent studies in range cattle production by the United States Department of Agriculture and the state experiment stations have brought out two facts of great importance to those interested in efficient livestock production. First, they have shown that the cost of production in beef cattle herds depends to a considerable extent upon the number of calves raised per hundred females of breeding age. Second, they have shown great variations in the number of calves born per hundred females of breeding age on the different ranches in the areas under study.

## DATA OBTAINED BY SURVEYS IN THE RANGE CATTLE STATES

The Federal work in this field was carried on by Klemmedson and Parr. In 1922 Klemmedson(14) [3] made a study on 41 ranches in Colorado containing 22,285 cows and their calves. He states, "The costs of production differ widely with the locality and with the system of management, both in the same year and from year to year. There is a marked variation from ranch to ranch as the following cost figures show. As an illustration the five ranch herds shown below, with no perceptible difference in range, feed, water facilities, quality of animals or animal losses, show large differences in production costs because one ranch had a calf crop of 70 per cent while an adjoining ranch had a calf crop of only 36 per cent."

The data mentioned above are shown in table 1.

On the 17 prairie ranches studied the percentage of calves raised varied from 33 to 83 per cent with an average of 56 per cent. On the 24 mountain ranches included in the work the calf crop varied from 36 to 76 per cent and averaged 56.7 per cent. Seven of the mountain

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[3] Numbers in parentheses refer to references listed in the back of this publication.

ranches kept the breeding herds under fenced pastures or fenced forest grazing land, where breeding could be controlled, and had 72.7 per cent calf crop. The remaining 17 ranches running the breeding herds on the open forest range produced an average calf crop of 50.1 per cent. The authors were of the opinion that this 22.6 per cent difference in the calf crop was due to the difference in method of handling the herds, but nothing is stated regarding feed supply in the two areas.

TABLE 1

Variation in Cost of Producing Calves on Five Adjoining Ranches in Colorado, 1922

| Ranch number | Calf crop % | Gross cost per calf |
|---|---|---|
| 7 | 70 | $32.50 |
| 2 | 67 | 39.78 |
| 14 | 56 | 52.02 |
| 40 | 51 | 45.11 |
| 13 | 36 | 66.12 |

In 1920, 1921, and 1922 Parr and Klemmedson[20] made a similar study in the northeastern range area of Texas on 15 ranches containing 38,511 cows and their calves. In this work they state: "The items which enter into the cost of producing a calf at weaning are divided into two groups—operating costs and deductions from profits. The prime production cost of a calf is the total operating cost divided by the number of calves produced."

In describing the breeding herd they state: "Two-year-old heifers are included in the cow herd in view of the fact that the prevailing practice is to breed heifers to calve at two years of age. Aside from the ratio of serviceable bulls to the number of cows, range conditions are an influencing factor in the calf crop. Scant range during the spring and summer invariably results in a small percentage of calves the next spring."

On the 15 ranches the percentage calf crop varied from 94 per cent on ranch No. 6 to 51 per cent on ranch No. 15, and the operating cost of production per calf varied from $12.49 on ranch No. 6 to $31.56 on ranch No. 13. They state: "Varying practices show their effect in the operation results and important among them is the method of handling the bulls. On 10 of the 15 ranches the bulls were taken out of the cow herd in the fall for conditioning and were returned to the cow herd around June 1 of the following year. On the other 5 ranches the bulls were kept in the cow herd during the entire

year. The ranches on which the bulls were removed from the cow herd had a 77 per cent average calf crop for three years, and on the ranches where the bulls were not removed from the cow herd the average calf crop was 64 per cent for the same time. The conditioning of the bulls was in a measure directly responsible for a 13 per cent increase in the number of calves dropped. Uniformity of age of calves and a saving of feed in wintering cows are facts resulting from the practice that are real advantages."

During the years that the above work was being carried on the same authors[21] also made a similar study on 15 ranches in north central Texas and extended it in 1923 to 40 ranches carrying 65,458 cows and their calves. In those parts of this area where calves were produced at unusually low costs there were high calf crops and vice versa.

Under variations in calf crops, they state: "The number of calves per 100 cows is the vital factor in the cost of producing calves under ranching conditions. There is a direct relationship between the net cost of calves raised and the per cent calf crop." The figures bearing on this point are shown in table 2.

TABLE 2

The Influence of Size of Calf Crop Upon the Net Cost Per Calf

(43,367 calves under study in north central Texas, 1920 to 1924.)

| Per cent of calf crop (by groups) | Number of ranches in each group | Number of of calves | Net cost per calf (4 yr. average) | Per cent of total calves |
|---|---|---|---|---|
| 30–40 | 1 | 590 | $43.92 | 1.4 |
| 40–50 | 2 | 585 | 49.21 | 1.3 |
| 50–60 | 14 | 11,880 | 36.15 | 27.4 |
| 60–70 | 18 | 8,020 | 38.88 | 18.5 |
| 70–80 | 22 | 10,848 | 28.03 | 25.6 |
| 80–90 | 22 | 9,749 | 25.46 | 22.5 |
| 90–100 | 5 | 1.695 | 22.15 | 3.9 |
| Totals and averages | 84 | 43,367 | $31.95 | 100.0 |

In regard to the much discussed question of the number of cows per bull they made the following statement, based on the work in this area:

"A study of the range conditions in connection with the calf crop on 15 ranches upon which data have been obtained for four years shows that, 7 ranches, running 1 bull to 19 cows, and stocked at the rate of 10.4 acres per cow unit in 1922 on which range conditions were below normal had a calf crop of 49.1 per cent. Eight other

ranches running 1 bull to 22 cows and stocking 9.2 acres per cow unit on which the range was normal in 1922 had a calf crop of 80.5 per cent in 1923, showing that the condition of the range was the important factor. Even though the 8 ranches were stocked heavier than the 7 ranches they had a 31.4 per cent higher calf crop due to better range conditions.

As a rule there is less variation in the calf crops on the smaller than on the larger ranches, due, in all probability, to the fact that the breeding herds on the small ranches are generally maintained in better condition. A higher percentage calf crop is generally obtained on the smaller ranches.

Likewise a comparison of calf crops on ranches making a practice of breeding heifers to calve at two years of age compared with those that breed to have the first calf dropped at three years shows less than 1 per cent difference in the calf crop in favor of breeding heifers to calve at three years of age."

## RESULTS SHOWN BY SURVEYS IN FAR WESTERN STATES

In addition to the work above reported by the Federal investigators in Colorado and Texas, information has accumulated in other far western states on this subject. Hilts[12] in a study of the 1924 calf crop in Nevada found in the northern district an average crop of 66 per cent with a variation from 25 to 95 per cent; in the central district an average of 61 per cent with a variation from 25 to 95 per cent and in the southern district an average of 51.5 per cent with a variation from 25 to 85 per cent. Some cattlemen obtained 30 calves more per 100 cows than others operating under the same conditions. He also observed that cows turned out in good condition in the spring produced 18 more calves per 100 than were obtained from cows turned out in poor condition.

The abortion loss from all causes was 3 per cent in the northern district; 2.1 per cent in the central district and 1.2 per cent in the southern district with a state average of 2 per cent. The contagious abortion loss in infected herds was 5 per cent in the northern; 6.8 per cent in the central and 4.5 per cent in the southern district, with an average of 5.5 per cent. It is, therefore, evident that abortion is a minor factor in the Nevada area.

Potter[22] states, "The well known veterinary authority, Fleming, estimates that the average breeding efficiency of cattle is about 78 per cent. The carefully managed herd will do somewhat better than this and will sometimes go as high as 85 per cent or 90 per cent. On

the other hand, however, the average herd on the open range will not do so well, the average being about 60 per cent, although with good care and good bulls an average of 65 per cent to 70 per cent is obtainable. This percentage largely determines the cost of the calf."

In 1925, Potter[23] states that the percentage will vary greatly in good and bad years. Also that cattle handled in small pastures will produce about 10 per cent higher calf crop than range cattle.

In unpublished data collected by E. B. Stanley, of the Arizona College of Agriculture—on 63 cattle ranches in the year 1925 an average calf crop of 32.14 per cent was obtained. At this particular time the economic and physical conditions of the range livestock industry were at a very low ebb. He stated, however, that it was the concensus of opinion that the average calf crop in Arizona will approximate 40 per cent over a period of years, although a number of cow outfits attained as high as 85 or 90 per cent calf crop in 1927. This was to be considered an exceptional condition and would be offset to a considerable extent by the drought years which occur periodically in that and adjoining states.

In 1927 Walker and Lantow[32] published range cattle studies made in 1925 on 127 ranches in New Mexico. The data collected showed that 78 per cent of all losses on the ranches studied were due to starvation. This means that about 12 out of every 100 head of cattle on ranches in the state die of starvation, varying in the different districts from 5 to 15 head per 100.

There has been criticism directed against some experimental work in this country because the animals were kept on a restricted food intake. With this type of evidence on the range, one can readily see that there are thousands of head of animals in this country on very restricted nutritional regimes that are not in any experimental tests. It must also be recognized that experimental animals may be placed on extremely rigorous nutritional regimes and yet not exceed that which is the common lot of commercial stock cattle herds in very wide areas of the semi-arid southwest range area of the United States during parts of practically every year.

The above workers state that New Mexico is almost constantly in the throes of a drought. Ranchers in planning future operations are more and more contemplating running just enough cattle to utilize the grass during the poorest years. Feeding bulls cottonseed cake during both the winter months and the breeding season appeared to increase the calf crop. It was also noticed that an increased calf crop was obtained when the 1924 forage on the range was sufficient or when feeding was practiced with both roughage and concentrate.

Feeding cake alone in the absence of sufficient forage did not appear to increase the calf crop. On all the ranches studied a 57 per cent calf crop was born and a 48 per cent calf crop was branded, thus increasing the cost of production per calf from $26.80 at birth to $32.15 at branding time. In these studies it was found that the larger the ranch the greater the cost of production and the smaller the percentage calf crop born or branded.

In 1924 Adams[1] in a survey on cost of producing beef in California, found that cattlemen's statements of their calf crop ranged from a low of 50 per cent to a high of 90 per cent and averaged for the 32 records 67.3 per cent.

## FAILURE TO CONCEIVE AS COMPARED TO PREMATURE DELIVERY

Failure to conceive, or expulsion of the fetus before it is viable has the same result so far as actual percentage calf crop, is concerned. It is readily appreciated, however, that they are fundamentally entirely different conditions. In failure to conceive we have a condition in which the female did not come in estrum or did not breed, or having come in estrum and having been bred, something either on the part of the female or of the male prevented conception. In premature delivery all of the essentials for the establishment of pregnancy were existent, but after conception occurred some other factor came into play which prevented the normal development of the fetus and caused its expulsion before the end of the gestation period.

In the areas where low percentage calf crop has been observed for many years a number of factors have been assigned as the cause.

Recently, with the great amount of study being made on infectious abortion and the definite knowledge that it exists in range cattle, greater emphasis has been placed on this as an important factor in calf crop.

## EVIDENCE THAT FAILURE TO CONCEIVE IS THE PRINCIPAL FACTOR IN SUSTAINED LOW CALF CROP OVER WIDE AREAS

It is true that bovine infectious abortion does attack range cattle and may in individual cases over one or two seasons be the cause of extremely low percentage calf crops. At one time it was thought that the extension of this disease from the dairy herds to the ranges would be a very serious permanent factor in the calf crop. However, experience has shown that from the standpoint of the individual herd

abortion is a self-limiting disease. This is due to the gradual acquiring of a tolerance or immunity to the organism so that it will cease to produce its manifestation over a varying period of time even though no special precautions are taken to limit its ravages. This is manifested in range herds more frequently, and in a shorter period of time, than in dairy herds because the latter are crowded together in comparatively small quarters, which gives much better opportunity for the spread of the infection. Very great reductions in the incidence of the disease have been observed from one year to the next. Potter[24] in his work on range cattle in western Kansas, observed this in herd after herd and did not hesitate to predict the cessation of the disease after two years. The percentage of second-aborters in range cattle is low. The continuance of the disease is frequently carried on in a low percentage by the abortion of first-calf heifers. These receive the infection from adult cows which have aborted, and which remain carriers and disseminators of the infection even though they no longer manifest any observable evidence of the disease.

Hilts[12] showed in Nevada that the state average abortion loss from all causes was 2 per cent. In herds actually infected with contagious abortion the premature births averaged 5.5 per cent. Such evidence shows clearly that the great variation in calf crop extending, on different ranches in the Nevada study, from 25 to 95 per cent could, under no circumstances, be entirely attributed to abortion. This evidence, together with that existent in all of the western range area, shows that the factors which prevent the establishment of pregnancy are the principal factors involved in the greatly varying percentage calf crops over a series of years.

There is, of course, more than one factor involved in failure to conceive. For many years it has been ascribed to methods of herd management, and, recognizing the broad field that such a term covers, it is correct. Within this general statement are several factors to be considered however, among which may be mentioned a definite breeding season, proper proportion of males and females and the plane of nutrition of the animals.

There are a number of advantages in having a definite breeding season in range cattle herds and this should always be practiced when possible. It allows for conditioning of bulls in the non-breeding season, uniformity of age of calves, limiting range of females during breeding season so they will have better opportunity to come in contact with males during estrum, and definite knowledge as to the non-pregnancy of cows which have not calved in any one year. Proper proportion of males to females is of course a factor to be reckoned

with, although it may vary considerably, other conditions being favorable, without markedly changing the results. Bulls should be active and in a good state of nutrition. Cows should not be scattered in small groups or singly over wide areas as under such conditions estrum may occur several times without their coming in contact with a male. A number of years ago when Texas fever tick eradication was going on in California, range cattle were rounded up and dipped every 25 to 30 days. Evidence developed that the procedure increased the calf crop simply from the fact that bulls were brought in close contact with all the cows at 30-day intervals. It must be recognized, however, that destroying the ticks also had the effect of increasing the plane of nutrition of the animals. It is quite possible that a proportion of less than 1 bull to 15 breeding females may be a limiting factor in calf crop under unfavorable conditions. On the other hand, with otherwise favorable conditions, 1 bull to 30 females may be sufficient.

## EXPERIMENTAL EVIDENCE THAT FAILURE TO CONCEIVE IS PARTLY BASED ON PLANE OF NUTRITION AND MINERAL METABOLISM

The condition of nutrition of animals has an important bearing on the development of estrum. It has long been observed, for example, in range cattle that, during unfavorable years when feed is poor and weather conditions bad, causing mature non-pregnant cows to become very thin, no estrum is noticed until feed conditions are such that the animals begin to improve physically even though many months are required for this change to occur. If, therefore, the year has been one of severe drought the cattle become very thin and some cases of death from actual starvation may occur. The following fall or winter may be one of copious rainfall and open weather conditions, resulting in plenty of feed and constituting a so-called good year. Under such conditions it will take a considerable part of this good year for the animals to get back into a sufficiently high plane of nutrition for the normal development of the estrous cycle followed by breeding and the nine months gestation period, thus running into the second year following the drought before the normal or high calf crop is obtained.

Evans[6] has shown that in the white rat certain nutritive regimes may permit growth to occur and still interfere with or prevent the normal rhythmic functioning of the ovary. This mechanism was shown to be influenced by qualitative and quantitative undernutrition. In a study of the normal appearance of the first cycle in the

particular colony of rats with normal diets he found that in 80 per cent of the animals the first estrus occurred between 37 and 55 days with an average of 47 days. With McCollum's standard diet I,[4] he limited the intake of this food by the animals so as to create partial starvation. One group of animals was kept at a weight level of 200 grams, a second group at 125 to 150 grams and a third group at 60 to 85 grams. For the first group the diet had to be reduced only slightly over that given the controls, while it had to be reduced to two-thirds for the second group and to one-half for the third group. The animals in the latter group did not exhibit an estrous cycle in 375 days. In the second group, 8 of the 10 animals eventually exhibited estrum. Its first appearance varied from 116 to 332 days and averaged 210 days. Two of the animals in this group did not develop estrum during the entire year. Even in the first group ovulation was seriously affected. There was delay in the appearance of the first estrum from the 50th to the 135th day with an average appearance on the 67th day, as compared to maturity at the 50th day in normal controls. It was, therefore, evident that a general or quantitative undernutrition depending on degree prevented or postponed the attainment of sexual maturity.

When animals were placed on carbohydrate-free diets, with protein neither high nor low, they grew normally and no significant injury to the sex physiology was produced. With diets deficient in salts it was evident that the sex impairment was much in excess of the impairment of growth. Without being able to explain this condition, the observation was made that depletion of salts is inimical not only to skeleton growth but to the normal rhythm of ovulation.

In general it was concluded that underfeeding affects time of maturity and ovulation history. The maintenance of ovulation rhythms and the capacity to have young constitute a more exacting test of a sound physiology than does growth alone.

There are some areas in the western range country such as southern Nevada where plant growth is so restricted by soil and weather conditions that the production of one calf every two or even three years is considered the average result to be expected.

[4] McCollum's Diet I consists of the following ingredients:

| | % |
|---|---|
| Casein (uncooked) | 15.0 |
| Whole milk powder | 10.0 |
| Sodium chloride | .8 |
| Calcium carbonate | 1.5 |
| Butter | 5.2 |
| Whole wheat (ground) | 67.5 |
| | 100.0 |

It is now generally recognized that minerals play an important part in animal nutrition and that calcium and phosphorus are two of the very important minerals that are found in the animal body. These elements are important in the formation of the skeleton but exist in more or less constant proportion in the circulating blood and are given off in very definite and sizable quantities in the milk. It must be recognized as conceivable, therefore, that animals may get sufficient food to supply their energy and protein requirements without getting sufficient minerals, particularly calcium and phosphorus, to maintain their normal mineral metabolism requirements. This is quite definitely recognized and understood to exist in iodine deficiency where various symptoms are observed in human beings and animals which are receiving a normal intake of food for energy and protein requirements. In animals this condition is manifested by hairless and goitrous offspring. Evidence is accumulating in various parts of the world that a variety of conditions may be manifest under prolonged subnormal intake of calcium and phosphorous. Some of these conditions are probably manifested in the function of reproduction and milk secretion.

The most exhaustive experimentation on this subject has been carried out by Theiler[26] and his associates in their studies of *lamsiekte* or parabotulism in cattle on the South African veld. This is a disease caused by the toxin of the parabotulinus organism which is contained in decomposing tissues on bones eaten by cattle suffering from osteophagia or bone craving. The depraved appetite causes the cattle to ingest carcasses of small animals or green bone on the veld containing the organism and its toxin which is the direct cause of the disease. The indirect cause, however, is the depraved appetite which the work of Theiler from 1917 to 1921 caused him to believe to be due to the lack of phosphorus in the vegetation.

However, this author states: "Incidentally it may be remarked that a high ratio of lime to phosphorus in the mineral matter of a plant may possibly have a similar effect to a low absolute percentage of phosphorus, and we are yet prepared to substitute an excess-lime hypothesis for a phosphorus-deficiency theory. We do not yet wish to bind ourselves to any one single explanation of the observed facts, but wish to avoid adopting too simple an explanation for what may yet turn out to be a complicated business."

Further extensive experiments were carried out by Theiler, Green and DuToit[27] to determine the extent to which phosphorus entered as an economic factor in beef production, with striking results published in 1924 from which the following is quoted:

"Phosphorus is unquestionably a limiting factor in the growth rate of cattle, and a dominating factor in the maintenance of live-weight under ordinary conditions of veld grazing, so that the nutritional aspects of the investigations now altogether overshadow the original problem of disease. Since the areas over which the nutritional factors apply are far wider than those over which *lamsiekte* occurs, the annual financial gain to the stock-raising industry in the future can easily be made far to exceed the annual financial losses from *lamsiekte* in the past. Indeed, by focusing attention upon specific nutritional deficiencies of South African veld, the disease can almost be said to have been 'a blessing in disguise.'

"Increase of milk yield of cows, better calves at birth, more rapid growth of young stock, and superior fattening of adult cattle, all follow simple bone-meal feeding, and agricultural propagandists might well carry the phrase 'Bone-Meal for Beef' as a slogan cry over all the phosphorus deficient areas of the Union."

In South Africa, phosphorus deficiency is a general characteristic of the soils over wide areas. The chain of evidence in that country begins with poor soil and ends with poor beef. Pica or depraved appetite was so common that the South African farmer had observed it all his life and considered it normal. Theiler and his associates brought out the fact that osteophagia means consistently poor beef. Bone meal fed in quantity to stop osteophagia did not however furnish an optimum of phosphorus for maximum growth and fattening. For example, in three calves, one fed no bone meal, one just enough to prevent osteophagia and a third fed excess, the gains in weight over a period of 16 months amounted to 166 pounds, 295 pounds and 352 pounds, respectively. In regard to the per cent calf crop Theiler et al.[30] state: "Of the cows receiving the bone meal ration, 80 per cent calved normally—a fair calf crop when the varying age and character of the herd is taken into consideration. Of the control cows only 51 per cent calved." The investigators definitely showed that phosphorus could be supplied in the form of wheat bran, bone meal, sodium phosphate or phosphoric acid to produce the desired results. In the last form, however, it tended to disturb the base acid equilibrium of the body and was used experimentally to prove that phosphorus was the element lacking, rather than as the best practical means of furnishing this element. Bone meal was established as the best and cheapest form in which to supply the phosphorus.

In one series of experiments, chalk was given to a group of animals but they maintained their craving for bone and in the latter part of the period seemed to manifest increased osteophagia. There

had been no evidence of deficiency of lime in the vegetation of the area and the practice of mixing lime with bone meal was probably contraindicated because of the possibility of an increased amount of lime over that contained in the bone meal decreasing the availability of food phosphorus during digestion. Attempts at supplying the soil with phosphate fertilizer (500 pounds to the acre, using superphosphate) were successful but it was not a practical procedure on account of expense. Where bone meal was fed to the cattle directly, results were quicker, costs less and still a high percentage of the ingested material passed out with the feces and thus gradually added soil fertilizer. Their work showed also that sheep were susceptible to phosphorus-deficient vegetation but that this species of animals could be handled in areas where cattle were unprofitable. Sheep showed osteophagia in a very slight degree which could easily go unrecognized, but at the same time were improved by bone meal feeding given in the amount of 2 ounces per week with an equal weight of salt in the form of a lick.

In the feeding of bone meal to cattle in these areas the dose varied—one ounce for an old ox, 2 ounces for a steer or heifer, and 5 ounces for a lactating cow, fed every day except Sunday. In some cases where this was impractical feeding three times weekly gave very good results. Feeding at less frequent intervals they found to be of much less value often doing very little good at all. Weekly feeding of the material failed to prevent osteophagia irrespective of the dose given. The interesting question of whether the cattle supplied with bone meal thus making increased gains did so as a result of eating more feed or by better utilization of the same amount of food, was studied and answered as follows:

"(1) The cattle receiving bone-meal eat more hay, increase more in weight, and lose their osteophagia. For the first three months the controls retain their osteophagia, gain only 30 lb. per head in weight, and eat from 60 lb. to 80 lb. of hay per head per week, or about 10 lb. of hay per day in addition to the 2 lb. of Fanko. The cattle receiving bone-meal promptly lose their craving, eat 90 lb. to 100 lb. of hay per week, or about 4 lb. more per day, and gain 110 lb. per head in weight—practically four times as much as the controls receiving no bone-meal.

"(2) At this point (October, 1922), the experiment was 'crossed,' in order to make quite sure of excluding potential idiosyncratic differences between the two groups, i.e., the bone-meal was taken away from one lot and given to the other lot. The effect was very striking. Within a month the osteophagia curves and hay consump-

tion curves cross, i.e., the osteophagia returns and the food consumption diminishes in the lot from which the bone-meal was taken away; while osteophagia disappears and food intake rises in the lot to which the bone-meal ration was transferred.

"The weight curves respond in the same direction, and within four months, the previously inferior controls have not only made up their leeway of 80 lb. but have actually surpassed the lot deprived of bone-meal."

Evidence was developed that animals lacking phosphorus actually consumed food in considerable excess over that required for maintenance but the extra ration served no useful purpose.

In a later publication Theiler et al[28] show that the seasonal limits of the absolute daily intake of phosphoric oxide range from about 38 grams early in November to below 11 grams in June on the affected area in that country. The former figure represents sufficient for ordinary requirements except high milk production but the latter is below that at which marked osteophagia develops. The average physiological limit for development of osteophagia is, therefore, indicated at about 27 grams phosphoric acid in the day's grazing for cattle of about 1000 pounds live weight.

In the areas under consideration the cattle live for ten months of the year at a very low line of phosphorus metabolism and have craving as the manifestation of this nutritional deficiency.

South Africa is not the only part of the world where bone craving is manifested in livestock. In Norway, there exists a high incidence of a different condition in cattle known as osteomalacia which has been studied extensively for many years and the work reviewed by Tuff.[31] While the exact nature of this trouble is still not fully understood in all particulars it has been rather definitely established that the principal underlying factor is deficiency of the mineral elements of the food. In South Africa phosphorus was the only element lacking while in Norway calcium was definitely deficient and probably also phosphorus which accounts for the entirely different manifestation. Tuff also mentions the importance of the proportion between acid and base equivalents in the total foodstuffs and the proportion between the various metal-ions in the inorganic salts in the food which he states are of the very greatest importance for a normal metabolism of minerals.

The disease is more frequently manifested during a year of drought and the year following.

In Aust-Agder, Norway, in 1862 it was reported that the disease appeared in certain forms every year and it was found that during

winter these cattle were fed chiefly hay and straw. When this forage was examined chemically in 1878 the ash content was found to be very low—2.6 per cent or two-fifths of the normal in good hay. The percentage of lime and phosphoric acid was only one-third of normal.

Throughout the winter in these districts in Norway it had long been the custom for bones from housekeeping to be kept and, together with those sometimes brought from districts where the disease did not occur, were crushed and fed to the cows during the summer. This treatment was universally used in the most pronounced affected districts and without it the livestock perished. In those districts an interesting observation in sheep was pronounced wool eating with rachitic embryos some of which had deformities. Bony enlargements around the joints were also frequent in cattle and horses. When only hay and straw were fed during the winter and no commercial fertilizer used the disease appeared at all seasons. With stronger winter feeding including concentrates, and commercial fertilizer on the tilled land supplying the winter fodder, the number of cases during winter and spring was reduced. Experience showed that the best means of preventing and of curing the disease was to supply the cattle with crushed bones. It was common to find the condition in one district with a sharply defined boundary from an adjoining district where it never occurred. This points to the condition of the soil as the primary cause of the disease, which was in fact established by Kolderup and Aarstad, and cited by Tuff.[31] They found a rocky substratum containing 0.002 per cent phosphoric acid in the affected district and a substratum containing 2 per cent of phosphoric acid in the unaffected areas. The percentage of lime in both types of rock was high. An analysis of the loose soil and of the hay that grew on it showed both to be considerably poorer than normal in both phosphoric acid and lime. Thus the hay in the affected area showed .36 per cent CaO and .15 per cent $P_2O_5$ (phosphorus pentoxide) as compared to .88 per cent and .44 per cent respectively in the unaffected area. With this progress of reduced intake of calcium and phosphorus, symptoms of the disease appear as deformity of the skeleton, cramp in the muscles, disturbance of the brain, reduced fertility, anemia; and finally a complete cachectic condition, and fracture of bones. Affected animals have a reduced appetite and a craving to eat abnormal substances. Tuff[31] states, "Even for a normal continuation of the stock the existence in the food of sufficient mineral substance is of the greatest importance. Thus it is generally observed in certain districts in Norway that years of osteomalacia are followed by periods of barrenness, a number of the animals, especially the heifers, showing

no signs of heat during the latter part of the winter and in the spring. They do not grow sexually normal and consequently can not breed till after they have been on the pasture for part of the summer. Some stocks which have been very badly attacked have to undergo treatment with preparations of lime and phosphoric acid before the generative organs can once more function normally. During the war, with its dearth of fodder, similar observations were made in Germany."

The work of Emmerich and Loew[5] on experimental animals is cited as evidence of the functioning of the reproductive organs being dependent on a sufficient supply of necessary minerals. These investigators by giving calcium chloride in the feed of mice, guinea pigs and rabbits demonstrated that these animals not only had more young at each litter but also had more litters per year than the check animals.

In further substantiation of the relation of nutrition to reproduction some very interesting data have been collected on wild animals in their native habitats by Julian Huxley.[13] Reference is made to the excessive multiplication of field mice in the San Joaquin Valley, California, in 1927. Presumably due to favorable environmental factors a similar plague occurred in Scotland, in 1892–93. These plagues are sometimes accompanied by great gatherings of birds which prey upon the mice. In 1892, in Scotland, the supply of food for the short-eared owls was so great that they prolonged their breeding season into November and even that late in the year produced broods much larger than normal. Nevada was visited by a mouse plague in 1907 and it was estimated that mouse-eating birds and mammals gorging on the mice killed over a million of them per month and yet their numbers continued to increase. Huxley asks the question, "Why these sudden outbursts of generative energy on the part of rodents?" and answers, "That is a problem for animal ecology, the branch of biology which might be called scientific natural history —the study of animals in nature and their relations with their environment and with other animals and plants. The first thing the ecologist discovers is that the plagues are not such isolated phenomena as at first sight might appear. They are merely exaggerations of one part of a regular cycle. All small rodents appear to have the life of the species strung on a curve of numerical ups and downs, a cycle of alternating abundance and scarcity."

The lemming of Scandinavia is cited as the best known example of cyclical abundance. This animal of the mountains of Southern Scandinavia becomes so abundant every few years that the young

animals set off on migrations in all directions in enormous numbers. If they come to the sea they enter the water and swim out until they drown, the coast becoming strewn with their corpses. Other sorts of animals show the same rise and fall in numbers among which are cited the crossbill bird of the pine forests of central Europe, the Pallas sand grouse of the steppes and deserts of central Asia. Very interesting data were obtained from the Hudson Bay Company, which has kept records since 1825 of the number of skins of the various kinds of fur bearing animals brought in each year by their trappers. These show cycles of abundance and scarcity in muskrat, Canadian rabbit, skunk, fisher, mink, wolverene, marten, lynx, red fox and Arctic fox. The record for lynx, for example, varies from 30,000 to 70,000 at the peak to below 5,000 for the depressions. The very large numbers are obtained because the animals are reproducing faster. For example, the Canadian rabbit in bad years will produce only one brood of about three young, while in good years it will produce two or three broods and eight or ten young in each brood. Conditions favorable for the growth of plants will result in favorable food supply and increase in the small herbivorous animals, and these in turn by furnishing food supply to the carnivorous animals, will cause an abundance of these species. Huxley[13] states "We know of no single case of an animal changing its reproductive capacity, whether number of broods per year, or number of young per brood, so long as it is kept under really uniform conditions, while we know of a great many cases in which improved conditions of temperature, food, etc., do bring about an increase in reproductive output."

In 1927 Theiler, Green and Du Toit[29] published recent studies on minimum mineral requirements in cattle. In this paper they discuss the prevailing views on the question of relative proportions of mineral elements and divide them into three groups.

"(*a*) The older view that the ratio of mineral constituents in a diet is of little consequence provided the total amount of each essential is adequate; a sort of 'Law of the Minimum' applied to animal nutrition.

(*b*) An extreme modern view that the ratio is of dominant importance and may be responsible for nutritional disorders even if each constituent is singly present in sufficient amount.

(*c*) The intermediate view which considers the absolute intake as of primary importance, but also emphasizes the aspect of optimum relative proportions, and the influence of one mineral constituent upon the absorption and utilization of another."

These workers rather regard the current emphasis on mineral balance as exaggerated and regard the physiological capacity of the animal to adjust itself to varying ratios as being much greater than credited by many authors. In their experiments they deliberately attempted to subject their experimental cattle to fairly extreme variations of ratios. A diet was given consisting of 3½ pounds of hay, poor in minerals, and as much Fanko as they would eat with 2 ounces of blood meal to insure sufficient iron and to vary the protein moiety. Fanko is a cereal flake breakfast food consisting of the rolled endosperm of maize, of high energy value and fair protein content but very low in mineral constituents. To this basal ration varying mineral supplements were added in the different groups of cattle such as sodium chloride, potassium chloride, bone meal, chalk, and wheat bran for its phosphorus content. One group as a check on the vitamin factor had young fresh green forage added. Eight experiments, on 16 heifers one year old when the experiment started, were carried out over the period from September, 1924, to December, 1926. The work showed that mineral requirements for growth are higher in the case of phosphorus than in the case of calcium and a ratio of $P_2O_5$ to CaO so high as three to one is not necessarily disadvantageous. Certain observed abnormalities in calving they did not attempt to explain but with phosphorus deficiency, definitely abnormal calves were born. They also showed that *styfsiekte,* a disease of South Africa, similar to what European literature describes as osteomalacia, was due to lack of phosphorus. Vitamin deficiency of the diets had no adverse effects. They also showed that excess of basic over acidic constituents of a diet is not necessary and that cattle can grow normally to full adult weight when the usual alkaline reaction of the urine is shifted to the acid side.

It is logical to consider, with these definite findings in different parts of the world, that in all probability similar conditions might exist among domestic livestock in various parts of this country with its variable rainfall, soil conditions, etc. Recent years have definitely shown this to be the case. Along the coastal plains of Texas, so-called loin disease and creeps have existed in the cattle and have been under observation for some years. In the range cattle of this area about 75 per cent develop the bone chewing habit. Experiments with the feeding of bone meal were carried out by Schmidt[25] as a part of the investigations into the nature and prevention of loin disease. He also found varying degrees of bone chewing, some animals eating only sun bleached bone, while others would take foul smelling ones with putrid meat still clinging to them. This was such a common condition in

this area that it did not arouse the curiosity of the owners. In many cases the habit existed in cattle in such a satisfactory condition of flesh that one would not consider it to be caused by a craving for anything lacking in the feed. Animals that were fed bone meal eventually lost the bone chewing habit although in some cases five months or longer were required to do this. In general it was found that the more bone meal an animal could eat regularly the quicker the habit disappeared.

The animals fed bone meal and salt passed the winter in much better condition than the controls. With the advent of spring the difference was even more marked. The cows receiving the material became sleek and put on flesh much sooner than the controls and soon did not look like the same cattle of the previous summer. When difficulty was experienced in getting the animals to eat sufficient bone meal it was given in a mixture with salt—two or three parts of bone meal to one or two of salt; or two-thirds of a pound of cottonseed meal and four ounces of bone meal per head each day. Calves raised from cows receiving bone meal were in better condition than those from the control animals. Ten calves from the test cows at 200 days of age weighed from 250 to 365 pounds each, while seven calves from the control cows at the same age weighed 235 to 300 pounds each.

From the results of the work Schmidt concludes

"That feeding bone meal and salt mixtures as here used

1. Increases the gain in weight during the favorable season.

2. Cows thus fed rear better calves.

3. Effectively prevents creeps.

4. Reduces the losses from diseases other than those of an infectious character.

5. Finely ground rock phosphate can not be used to take the place of bone meal."

In certain parts of Montana bone chewing has been observed for many years and was reported upon by Welch.[33] He has brought out the interesting observation that before ranges were fenced cattle could drift during grazing over very wide areas and thus find forage to meet their requirements. Cattlemen had ascertained from practical observation that some areas were superior to others and that certain ranges were not at all suited to cattle grazing. With the confining of cattle under fence and utilization of the better soil areas for farming operations it was quite conceivable that cattle could be limited in their movements to areas where the forage did not supply all the essential substances required in their nutrition.

It has long been recognized that livestock raised in certain sections of this and other countries were of uniform high quality. The blue grass region of Kentucky may be mentioned as such an area in the United States.

Great variations were observed by Welch[33] in the amount of salt required on different ranches. In parts of the Yellowstone, cows were observed to require hardly an ounce of salt per month while on other ranges an ounce per day may be used by each animal.

In the affected areas in Montana the bone chewing symptom is confined to the animals on the native grasses or hay. They may be supplied with an abundance of this feed, and water, and yet present the picture of starvation. On only a few ranches, however, was the mineral deficiency so great as to cause actual death of the cattle, but poor calves and the general unthriftiness made the cattle business unprofitable. In some cases where the pasture vegetation changed, particularly by developing a thin stand of clover, the bone chewing habit disappeared. Feeding bone meal had the same effect and no difficulty was experienced, as a rule, in getting the animals to eat the bone meal even without mixing it with salt. Affected cattle eat a surprising amount when it is first supplied but this soon satisfies their craving and the amount is rapidly reduced. In most herds there are a few cattle which, once having acquired the habit, will retain it more or less permanently. The effectiveness of results from supplying bone meal in those areas in Montana can best be observed over a period of several years rather than of a few weeks or months or even of a year. This brings out the importance of a continuous supply of bone meal in such areas.

The most comprehensive work in this country on this trouble has been carried out at the Minnesota Station by Eckles, Becker and Palmer.[2] A mineral deficiency in cattle was found by these workers to exist in 32 counties in Minnesota. In a survey of the affected areas many farms were found on which cows were expected to produce a calf only once in two years and heifers sometimes did not show estrum until two years of age. In general the native wild hay was considered the cause of the trouble, but on one or two farms feeding of home grown alfalfa hay did not stop the appearance of the condition. In all cases where bone meal was fed no evidence of mineral deficiency existed except on two farms where it had not been given in sufficient amounts. The deficiency was found to be more severe after short pasture seasons due to drought.

Their experimental work on the prevention of depraved appetite through feeding bone meal, its production under controlled condi-

tions, and curing affected animals through addition of single mineral supplements, all tended to show that lack of phosphorus was the chief causative factor in the trouble. This lack also involved the inhibition of estrum. The possibility of low intensity of ultra violet light during the winter months and the lack of a factor supplied by green feed may also have been involved, in the opinion of these workers.

In a later publication, Palmer and Eckles[19] report studies made in the inorganic calcium and phosphorus in the blood of the affected animals and found further proof of the causes of the trouble outlined in the first publication.

The blood plasma of the affected animals was found to be abnormally low in inorganic phosphorus. This was found whether calcium carbonate was given as a supplement to the deficient ration or not. The calcium content of the plasma was normal in all cases. The product of the calcium times the phosphorus in these animals was rarely above 30 and frequently much below 20. In marked contrast to this was the normal composition of the blood of animals fed the deficient ration to which was added $NaH_2\ PO_4$ (sodium dihydrogen phosphate). In these cases the calcium times the phosphorus ranged from 50 to 75. The work of Kramer and Howland[15] has shown that rickets is to be suspected in children when the product of the calcium and phosphorus is below 30 and its existence is still probable when this is between 30 and 40.

In 1926 a report of a similar trouble in several counties in Wisconsin was made by Hart, Beach, Delwiche, and Bailey.[8] In the affected areas the trouble appeared in cattle on sweet clover pastures and in those being fed alfalfa hay in abundance, thus pointing to a phosphorus, rather than a lime deficiency.

By placing 6 animals from various affected herds on rations liberal in phosphorus for a period of 3 months a remarkable improvement was noticed. Each of the animals gained over 200 pounds, and one 322 pounds; the stiffness disappeared, hides became loose and supple, and milk production increased 50 per cent. The addition of cod liver oil added to make sure that there was abundance of vitamin D, which animals need to enable them to utilize calcium and phosphorus in the feed, did not seem to improve the ration. They suggest that better feeding will protect against this disease and recommend adding 20 to 25 per cent of wheat bran, which is rich in phosphorus, to the grain mixture. This would be impractical in range herds and the same result could probably be accomplished by the feeding of bone meal.

Elliott, Orr and Wood[3] in Part II of their investigation on mineral content of pasture grass on the British Isles state:

"1. The results of previous investigations showing that there is no striking difference in the energy value between good and poor pasture are fully confirmed.

2. Wide differences, however, do exist in the proportions in which the mineral constituents are present in different pastures.

3. These differences correspond closely with the respective value to the stockman of the pasture in which they occur, a high mineral content being associated with high nutritive value."

In general, they found that the forage in the so-called fattening pastures was higher in mineral content and protein than in the non-fattening pastures. They also found that the ash content of eaten grasses was higher than in that which was not eaten. In this connection, sheep having free choice in grazing showed a preference for herbage containing a higher percentage of mineral ingredients.

J. S. McHargue[16] of the Kentucky Station, has suggested the possible important functions in the plant's economy of certain elements, found in very small quantities in plants, such as manganese, copper, zinc, nickel, cobalt, barium, strontium, boron, arsenic, fluorine and bromine. In carefully controlled experiments it has been shown that plants in sand cultures containing the so-called ten essential elements will not grow after the food material of the plant seeds has been utilized. Under such conditions the addition of a small amount of a manganese compound increases the growth and a small amount of copper then added makes the plant still larger and more nearly normal. He states, "Marine and fresh-water mollusks are quite rich in manganese, copper and zinc. Birds apparently contain more manganese than some of the higher type of domestic quadrupeds. However, appreciable amounts of manganese, copper, zinc and boron are normal constituents of the tissues of domestic animals. These elements have been found in greater concentration in the embryo of such animals as have been examined, than in the tissues of mature animals of the same species. The liver, kidneys, spleen, pancreas, heart and brain contain more of these elements than the lean muscular tissues or the blood. However, their presence can be detected in the latter. The bluegrass region of central Kentucky is underlain with phosphatic limestones which, upon disintegration, produce a soil relatively rich in manganese, copper, zinc, nickel and cobalt, and the presence of these elements can be detected in the forage crops produced. It is therefore assumed that the presence of these elements in the herbage produced in this region is a contributing factor in the development of the superior specimens of livestock for which the country has long since attained a world-wide fame."

These statements are particulary significant in the light of the very recent findings of Hart, Steenbock, Elvehjen and Waddell[9] on the importance of copper as an essential factor in the diet of mammalia to prevent anemia. A shortage of iron has always been considered the cause of this condition and while their work shows it to be still the limiting factor the effectiveness of its administration depends on the presence of copper.

The recent wide use of liver as a cure for anemia apparently thus depends on the presence of minute amounts of copper. In ashing liver they found a pale bluish color which suggested the presence of copper. Rats showing marked anemia from a pure milk diet were strikingly cured when copper sulphate was added as a supplement to pure ferric chloride.

The herd of purebred beef cattle at the University Farm is kept under rather ideal conditions and on a high plane of nutrition. They get alfalfa and sudan grass pasture during the long summer and autumn seasons. In the winter, which is relatively short, they get alfalfa hay and corn silage. In the spring they are turned into a native grass pasture containing a variety of forage plants. It can thus be seen that a high percentage calf crop should be expected and such has been the case. The herd has consisted of about 41 head of females of breeding age representing the Aberdeen-Angus, Shorthorn and Hereford breeds. During the period from January 1, 1923, to January 1, 1928, a total of 206 cows were bred and 183 became pregnant, or 88.83 per cent. In this period occurred an abortion infection causing 19 abortions and several of these cows failed to breed the following year. Three calves died at birth from mechanical abnormalities, and two cows were killed during pregnancy. This left 159 calves weaned or 77 per cent. There have been several females in this group 15 years old or more kept to get additional offspring from them. The important observation in this herd is that a high plane of nutrition under these conditions favors rather than militates against a high percentage of calf crop.

## EVIDENCE THAT CATTLE ON CALIFORNIA RANGES MAY BE ON A LOW MINERAL INTAKE DURING PARTS OF THE YEAR

The foregoing discussion covers such serious shortage in the intake of minerals with the food that abnormalities are produced in the animals pronounced enough to be definitely classed as disease. It must be recognized, however, that variations from the optimum in mineral nutrition may vary greatly in degree. The results may be such slight changes from the normal that they can not be recognized by the closest observation of the animal. On the other hand, they may be so marked as to produce alterations in the physiological processes, even resulting in death. Early changes are noticed in alteration in the digestive tract. Thus Orr[17] in experiments on pigs with feeding stuffs poor in calcium, noticed the development of convulsive seizures and frequently gastro-intestinal disorders.

It has been shown that on diets practically lacking in minerals the experimental animals died sooner than when no food was given.

In a discussion of the importance of mineral matter in nutrition Orr[18] brings out the fact that minerals are important in regulating the interchange of fluids between the lumen of the intestinal tract and the blood. In the stomach the contents must be acid to allow the pepsin of the gastric juice to act properly. Increased acid in the upper part of the small intestine stimulates the flow of digestive juices from the pancreas. Increased mineral salts tend to cause a flow of fluid from the blood to the intestines. This is the manner in which salts act as a laxative. Low mineral intake with food is also manifested by reduced appetite. It is a common observation on our cattle ranges during the dry feed season to note the dry and comparatively hard condition of the feces of the cattle. This tends to increase as the feed becomes poor until the feces are evacuated in balls, and it is generally known that cattle are not doing well when their feces are in this condition. There is evidence that the mineral content of the feed is responsible for this condition. Mild bone eating has been observed in several counties in this state.

## STUDIES ON RANGE GRASS IN CALIFORNIA

In February, 1927, the operator of a large ranch in Merced County, California, communicated with the authors in regard to his observation of cattle chewing bones in that section. He also stated that two cows with calves at side were given bone meal. These cows ate from 1 to 2 pounds of bone meal each per day for a period of two weeks and for a considerably longer period a similar amount every two days. Daily consumption then gradually decreased. The bone meal was of low grade, coarsely ground and had a decidedly bad odor. The fact that these animals ate such quantities indicated a decided deficiency. The bone meal was probably poorly utilized on account of its coarseness. Until the time of the first communication the cattle had subsisted upon the dry feed of the previous year. Some young green forage was available in February.

The ranch is east of the San Joaquin River, comprising low land, and the general topography is level. It is typical of so-called "hog wallow" lands of which there is a considerable area. On this type of range there are alternate knolls and depressions, the areas of which are commonly not over a few square rods in size. White alkali is apparent in many of the swales. The knolls grow a luxuriant vegetation when there is sufficient rainfall. The vegetative growth in the low portions is stunted, seldom attaining a height of more than 4 to 6 inches. Cattle graze almost entirely upon the knolls.

The forage consists of bur clover (*Medicago hispida*), foxtail (*Hordeum murinum*), wild oats (*Avena barbata*), soft chess or cheat (*Bromus hordeaceus*), needle brome (*Bromus rigidus*), salt grass (*Distichlis spicata*) and other species of minor importance. The first four are most important. The amount of bur clover varies from season to season, sometimes being abundant and at other times relatively scant.

A herd of 225 head of cows was purchased in Texas in the fall of 1925 and brought to this ranch. The owner stated that they dropped 204 calves in the spring of 1926. They were rebred and from this same herd 68 calves were produced in the spring of 1927. It was the operator's opinion that it was a common experience for the percentage calf crop to drop after the females had been on this type of range for a year.

Two other herds of cattle were brought to the ranch in the fall of 1926, one a purebred herd of 155 head and the other a grade herd

of 100 head. Bone meal was placed in troughs in the pasture occupied by the purebred herd beginning about May 1, 1927. The feed was excellent at this time, but the cattle ate some bone meal. During the period from May to October they consumed about 600 pounds of bone meal. This is not an accurate measure of their appetite as the troughs were empty a considerable part of the time. The rate of consumption increased when the feed dried. Two hundred pounds of bone meal were placed in the troughs the first of July and were consumed within a few days. The cattle remained in excellent condition throughout the season due largely to an excellent crop of bur clover which makes very nutritious dry feed.

In 1927 these two herds weaned 71.6 per cent and 84.5 per cent calf crop, respectively. In October when the calves were weaned the owner supplied bone meal to both groups. They have now dropped their 1928 calf crop. The purebred herd produced an 86 per cent crop while the grade herd produced 88 per cent. Feed conditions were such this particular year that no advantage was obtained from feeding bone meal as it was supplied during the breeding season of 1927.

The seasonal sequence of grazing was roughly as follows:

During the early vegetative stages the cattle ate some of the dry roughage along with the new growth. When the new forage became plentiful the cattle grazed largely upon the foxtail which is among the earliest grasses. Later the other species of grasses were included and also bur clover to a small extent. Cattle do not graze bur clover extensively in the green stages where other feed is plentiful, due probably to its somewhat bitter taste.

The bur clover, foxtail and brome grasses dried at about the same time in the early part of May. The wild oats headed out during this month and at the last of the month still retained some green color. At this time the cattle were grazing the wild oats and the dried bur clover. At about this time the salt grass appeared. During the remainder of the season the cattle grazed the bur clover patches, getting stems, leaves and burs, together with some stems of dry grasses. They also took some of the salt grass. This grass retains some green color throughout the season. The bur clover supply was rather meager by October. Rains came early and by December the new feed was excellent, thus the season during which the cattle had to rely on inferior feed was rather short during this particular year. Frequently, however, under a similar rate of stocking the bur clover supply would be exhausted much earlier in the season and often rains

come late and new growth is meager due to cold weather with the result that good new feed is not obtained until February or March.

Forage samples were collected from time to time throughout the season and submitted to chemical analysis for calcium and phosphorus and in some cases other constituents of the ash. The data secured are shown in table 3.

TABLE 3

ASH ANALYSES OF RANGE FORAGE FROM MERCED COUNTY

(All figures are in percentage on the dry basis.)

| | Date | Condition | Total ash | CaO | $P_2O_5$ | Si | MgO | $Na_2O$ | $K_2O$ | Cl | Fe |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Bur clover | 3/28/27 | Green | 10.06 | 1.28 | 0.86 | 0.28 | 0.56 | 1.18 | 2.78 | 0.51 | 0.012 |
| | *3/30/27 | Green | 10.42 | 1.27 | 1.09 | | | | | | |
| | 5/31/27 | Dry | 9.45 | 1.36 | 0.55 | 2.17 | 0.99 | 0.42 | 1.68 | 0.47 | 0.119 |
| | 7/14/27† | Dry | 16.05 | 1.15 | 0.43 | | | | | | |
| | 7/14/27‡ | Dry | 13.03 | 1.45 | 0.49 | | | | | | |
| | 10/3/27 | Dry | 17.61 | 1.54 | 0.60 | 8.95 | | | | | |
| Clover burs | 5/31/27 | Dry | 5.91 | 1.13 | 0.83 | | | | | | |
| | 10/3/27 | Dry | 9.26 | 1.06 | 0.85 | | | | | | |
| Foxtail | 3/28/27 | Green | 9.97 | 0.43 | 0.83 | 3.37 | 0.28 | 0.94 | 2.54 | 1.02 | 0.013 |
| | 5/31/27 | Dry | 14.31 | 0.30 | 0.29 | 9.41 | 0.19 | 0.89 | 1.32 | 2.06 | 0.022 |
| | 10/3/27 | Dry | 12.42 | 0.32 | 0.30 | 8.52 | | | | | |
| | 12/20/27 | Green (6–8 in. high) | | 0.52 | 0.97 | | | | | | |
| Bromus hordeaceus | 5/31/27 | Dry | 9.10 | 0.43 | 0.25 | 4.63 | 0.32 | 0.40 | 1.43 | 1.00 | 0.013 |
| Salt grass | 5/31/27 | Green | 10.07 | 0.35 | 0.39 | 5.74 | 0.38 | 0.64 | 1.30 | 2.02 | 0.042 |
| | 7/14/27 | Green | 16.44 | 0.32 | 0.30 | | | | | | |
| | 10/3/27 | Partly dry | 28.68 | 0.39 | 0.23 | 11.95 | | | | | |
| Wild oats | 5/31/27 | Partly green | 9.10 | 0.21 | 0.28 | 6.05 | 0.15 | 0.67 | 1.05 | 0.95 | 0.022 |
| Composite sample (knolls) | 3/24/27 | Green | 8.88 | 0.66 | 0.82 | 3.02 | 0.36 | | | | 0.011 |
| | 4/22/27 | Seed stage | 8.24 | 0.60 | 0.52 | | | | | | |
| Composite sample (swales) | 3/24/27 | Green | 11.78 | 0.59 | 0.97 | 1.41 | 0.42 | | | | 0.010 |
| | 4/22/27 | Seed stage | 9.85 | 0.51 | 0.80 | | | | | | |

* Sample from University Farm.

† Collected where cattle were grazing. Sample contained some stems of grass plants.

‡ Collected outside of the pasture and was fairly representative of entire plant.

The foxtail, brome grasses, wild oats and salt grass were all relatively low in calcium even in the succulent stages. A decline is noted in the calcium oxide content of the foxtail from .52 per cent in the early vegetative stage to .30 per cent in the dry forage. Wild oats showed the lowest calcium oxide content of any of the grasses, namely, .21 per cent in the partly dried plants. The calcium content of the bur clover remained high throughout the season.

The phosphorus content of the grasses decreased rapidly as the plants approached maturity and dried. The vegetative part of the bur clover apparently decreased in phosphorus, but as would be expected the burs containing the seeds, retained a high calcium and phosphorus content throughout the season. During the late summer months it was difficult to obtain samples of bur clover which had an amount of leaves, stems and burs representative of the entire plant earlier in the season. Sample No. 1 collected July 14 was taken where animals were grazing and seemed fairly representative of the material as eaten. It probably contained a lower proportion of burs than sample No. 2 which was collected outside the pasture and contained leaves, stems and burs fairly representative of the entire plant. There were also stems of grass plants included in sample No. 1 which accounts to some extent for the lower $P_2O_5$ content.

Later in the season considerable dust was on the plants and was the cause of the decided increase in silica content. This is especially true of the last sample of bur clover and of salt grass, the latter having a sticky exudate thus collecting large quantities of dirt.

These data show that, aside from bur clover, the dried roughage contained an amount of calcium and phosphorus which is below that required for optimum nutrition. If the bur clover crop is meager and the cattle have to rely upon the dried grasses throughout most of the summer while still suckling calves, it seems probable that breeding efficiency would be interfered with resulting in low calf crop the following year. These dried grasses are also low in protein and can not be expected to furnish much above body maintenance requirements for energy.

A digestion trial by Mead and Guilbert of this station, data not yet published, with dried range grass from Mendocino County, collected by A. W. Sampson of the Division of Forestry, showed little or no digestible protein, 43.4 pounds digestible carbohydrate and .47 pounds of digestible fat in 100 pounds of the material. This forage contained .28 per cent calcium oxide and .38 per cent phosphoric acid. It contained about 60 per cent soft chess or cheat, the remaining 40 per cent consisting of needle brome, wild oats, foxtail and other species. A sample of the same forage cut earlier after the seed heads had formed and while still retaining the green color, contained .34 per cent calcium oxide and .79 per cent phosphoric acid, indicating further the rapid decrease of phosphorus which takes place as the plants mature and dry.

The $P_2O_5$ content of the grasses from the Merced range is somewhat higher than that reported by Theiler et al[28] in South Africa

which varied from .60 per cent in the early green stages to .09 per cent in the old dry grass. The dry grass is only slightly higher in phosphorus than the prairie hay and timothy hay from affected areas in Minnesota, as reported by Eckles, Becker and Palmer[2] where a phosphorus deficiency was clearly demonstrated.

The calcium oxide content is very similar to that of the forage in the Falkland Islands, as reported by Elliott, Orr and Wood[4] where a deficiency in the calcium was considered the limiting factor, as the $P_2O_5$ content of the grass was .54 per cent. The soil in the Falkland Islands is deficient in calcium and this deficiency limits not only calcium but other ash ingredients in the plants. The $P_2O_5$ content of grass was increased markedly by liming the soil.

The $Na_2O$ (sodium oxide) content of the Merced grasses varied from .40 per cent to 1.18 per cent while the chlorine varied from .47 per cent in bur clover to 2.06 per cent in salt grass. The sodium content is much higher than reported for pasture grasses in England and Wales by Elliott, Orr and Wood[4] and the chlorine content is high especially in the salt grass. This grass is decidedly salty to the taste, especially late in the season. Cattle on this range eat very little salt. Apparently they secure an adequate supply from the forage. The ratio of sodium to potassium is relatively narrow which would also tend to diminish the salt requirement.

The iron content appears to be sufficient, so that there is no reason to believe that iron deficiency is concerned. There does not appear to be anything unusual in the magnesium content of the forage.

Theiler[28] et al computed roughly the minimum requirement for $P_2O_5$ below which osteophagia appeared, by assuming 8 pounds of "starch equivalent" to be the ordinary energy requirement for a 1000 pound grazing animal, not counting growth or milk production. The energy intake was considered the limiting factor in amount of forage consumed. He computed the starch value of the forage at different seasons and determined roughly the total food and total $P_2O_5$ intake daily. By this means he shows a $P_2O_5$ intake of 38 grams daily during the season of highest intake when the grass was in the early vegetative stages. From this time the amount ingested rapidly declined to 11 grams daily on the old dry grass. By comparing the records of the percentage of osteophagia in the cattle he arrived at an intake of 27 grams daily as the amount below which the incidence of osteophagia is high.

The estimated starch value of the Merced range grass is 28 pounds per hundred weight of the material. A thirty pound daily intake for a 1000 pound animal would yield slightly over 8 pounds of "starch

equivalent.'' This amount of dry matter is close to the maximum which can be handled by a 1000 pound animal and probably in excess of what it is able to obtain on the range.

The average $P_2O_5$ content of the dry grass from June on to the time of new growth was about .28 per cent. Thirty pounds would supply .084 pounds or 38.1 grams of $P_2O_5$ or an amount above that found by Theiler as required to prevent decided osteophagia. This together with the fact that the phosphorus content of the grass is relatively high during a longer season of the year, even if bur clover is absent, probably accounts for the relatively small amount of bone chewing noted by cattlemen in this district.

The South African studies have shown, however, that a nutritional deficiency exists on an intake above that where osteophagia is evident. This is manifested by stunted growth and low milk yields which are quickly improved by bone meal feeding. Hart, Steenbock and Humphrey[10] in their study of the influence of a ration, restricted to the oat plant, upon reproduction in cattle, concluded that the principal deficiency was in calcium and that the ration of herbivorous animals should contain at least .45 per cent CaO for high reproductive efficiency.

It seems clear from the above discussion that the dry range grass is deficient both in calcium and phosphorus and, in addition, the conditions for their assimilation are probably not favorable. The work of Hart, Steenbock, Scott and Humphrey[11] casts some doubt as to whether cattle are favorably affected in regard to mineral metabolism by direct sunlight, and the general appearance of the forage would certainly not suggest high vitamin D potency.

## POSSIBLE DEFICIENCIES IN OTHER AREAS

A form of osteomalacia occurring chiefly in dairy calves has been found in Kings County at irregular intervals and was reported upon with illustrations by Haring[7] in 1922. (See figures 1, 2 and 3.)

On one ranch in a single year 15 out of 18 calves had broken bones and had to be killed. Only one milk cow out of 27 became affected and she recovered. The calves became affected even while being pastured on apparently good alfalfa pasture. When they were removed at weaning time to another field only one mile away they did not develop the trouble.

No phosphorus determinations were made on the samples of feed taken from the pasture. Samples of hay containing alfalfa and other grasses showed a $P_2O_5$ content varying from 0.40 to 0.53 and their

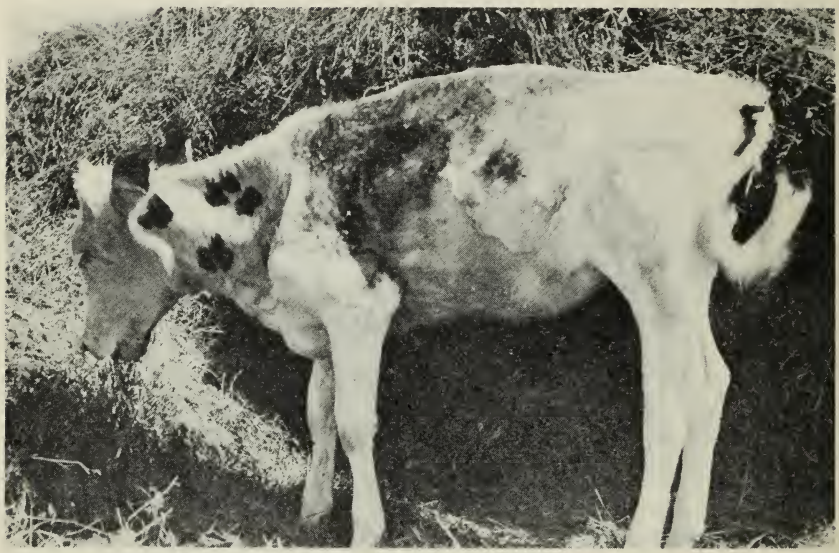

Fig. 1.—Side view of a case of osteomalacia in Kings County, May, 1921. (After Haring.)

Fig. 2.—Front view of same case as shown in figure 1. (After Haring.)

CaO (calcium oxide) content was high, varying from 1.54 to 2.21. One analysis of salt grass in the alfalfa hay that was separated and tested alone showed a $P_2O_5$ content of 0.09 and CaO content of 0.27. It was also stated that in some cases osteomalacia developed in animals fed on hay consisting of salt grass and foxtail, and that these animals recovered when fed from a stack of alfalfa hay.

In the winter of 1917 and 1918, rains came very late and green feed was not available until February in parts of the state. In January a peculiar lameness of dairy cows developed along the coast north of Santa Cruz. This condition occurred on the ranches feeding red oat hay. In the center of the area one ranch raised and fed alfalfa hay and no cases occurred on this place.

Some of the animals were so badly affected that they would stand and try to move around, resting the weight of the front part of their bodies on the knees. With the growth of green feed the trouble disappeared and since that time pasture has always been available much earlier and no cases have been reported.

At the time, one of the worst affected cases was killed and a post-mortem examination made including sectioning of the phalanges of the front legs. No definite conclusions were reached at the time regarding the trouble, but it was considered to be due to nutritional causes.

An inquiry from a cattleman regarding the supplementary feeding of beef cattle in San Bernardino County contained the statement that his cows failed to come in heat on his pastures while suckling calves and thus failed to have a calf each year. This man also stated that he had overcome the difficulty by feeding chopped citron and wheat bran. Wheat bran is especially rich in phosphorus, furnishes a fair amount of protein and is probably largely responsible for the good results obtained.

Occasional cases of bone chewing have been reported in certain sections of the Sierra foothills. In much of this country the range forage consists largely of the grass species along with a varying amount of alfilaria. The alfilaria is good early feed and the grass species are fairly nutritious in the green stages. On this type of range, cattlemen depend generally upon high mountain range for summer forage and come back to the lower range in the fall. Frequently the cattle must subsist for a considerable length of time upon the old forage on the lower range before new feed is available. Meager data are as yet available upon the nutritive value of the forage on the high mountain ranges. It is, however, common expe-

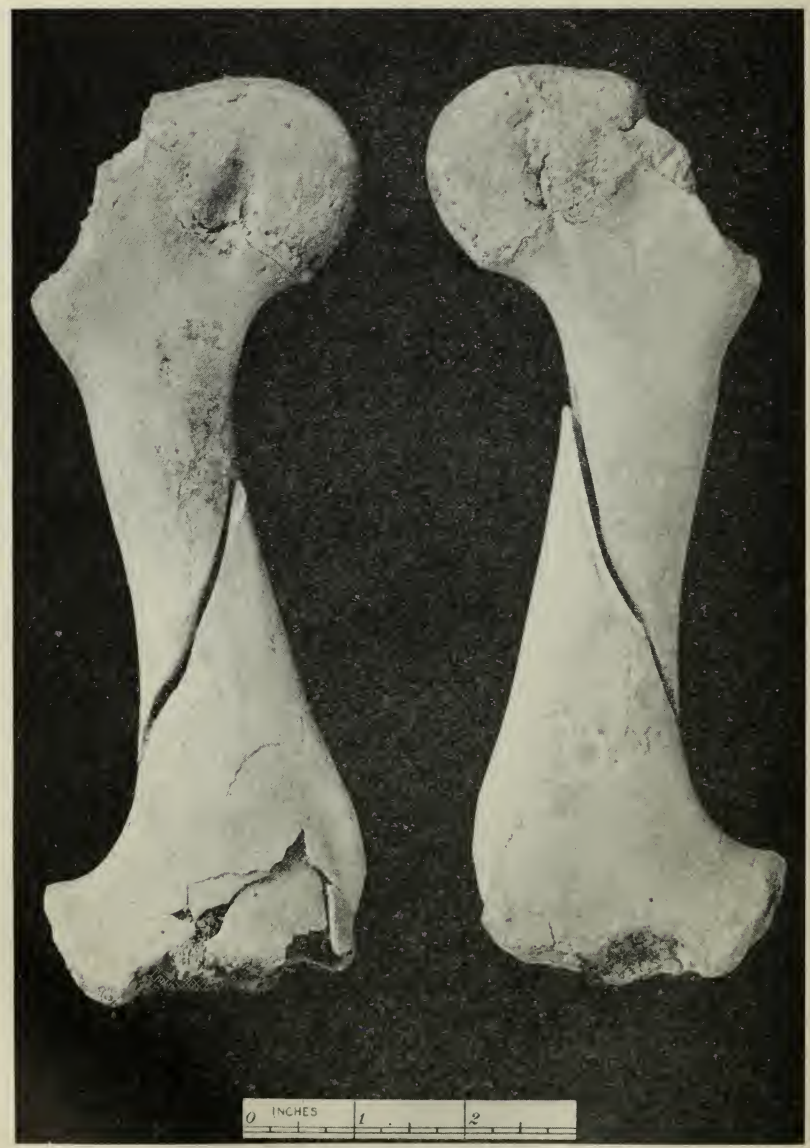


Fig. 3.—Fractured humeri of Holstein heifer born in the spring of 1921 in Kings County. Pastured on alfalfa, developed symptoms in November, was moved one mile away and improved. Was returned in January, quickly relapsed and broken legs necessitated slaughter January 25, 1922. (After Haring.)

rience for cows suckling calves to come out in thin condition in the fall. The logical time for the breeding cow to replace nutrition reserves lost in calving and during the suckling period is in the fall after weaning time. Since a large percentage of the weight of the unborn calf is also produced during the last few months of pregnancy, breeding cows should be gaining at this time. Failure to gain in this period means that the increase in the weight of the fetus is obtained at the expense of the tissues of the mother. If the cow is already thin, the results are weak condition at calving time, difficult parturition, a weak calf and a poor milk supply. Even on good spring feed the cow may not get in condition to breed and thus may miss calving one season in order to get back to an adequate plane of nutrition.

When cows must depend upon the old feed of the grass type very little if any gain in weight can be expected, and frequently they will lose weight. Under these conditions it probably is not possible to make replacement of mineral reserves. It is recognized that nutritional deficiency resulting in thin condition and impaired reproductive function may be due to the inability to secure an adequate quantity of feed in a day's grazing as well as to specific deficiencies in the quality of the feed. In other words, a limited amount of fair quality feed may have the same effect as a feed which is definitely deficient in one or more nutrients. Frequently the conditions which produce a low quantity of forage will also produce poor quality.

Adjusting the rate of stocking of ranges to avoid serious feed shortage, even in the poor years, is of utmost importance from the standpoint of efficient production and reproduction in the cattle and the maintenance and improvement of the range.

Since it is in the fall that the poorest quality of feed is available and since this is a critical period for both the cow and the unborn calf, it is important to improve the conditions by supplemental feeding as much as it is economically possible to do so.

Table 4 shows the changes in the organic constituents and calcium and phosphorus in range grasses at different seasons of the year.

Sample No. 1 was a mixture of range grasses from Mendocino County. It was taken from forage which was cut in the fairly mature but green state and made into hay. The second sample was collected from the range in August. The chief difference in these two forages is in the protein and phosphorus content. These data show the possibility of furnishing a feed of much higher value for the cattle when they come out of the high mountain ranges in the fall, by simply cutting and raking the forage into piles or windrows before it matures and dries.

## TABLE 4

### Chemical Composition of Range Forage at Different Stages of Growth and Curing

| Sample | No. | Date | Condition | Locality | Crude protein | Ether extract | Nitrogen free extract | Fiber | CaO | $P_2O_5$ |
|---|---|---|---|---|---|---|---|---|---|---|
| Soft chess (60%), wild oats, foxtail and other species (40%) | 1 | 5/6/26 | Green-seed fairly mature | Mendocino Co. | 7.08 | 1.31 | 42.27 | 28.52 | 0.34 | 0.79 |
| | 2 | 8/12/26 | Dry-exposed all summer | Mendocino Co. | 3.61 | 1.07 | 45.25 | 31.46 | 0.28 | 0.38 |
| Foxtail | 3 | 3/28/27 | Green-heads forming | Merced Co. | 16.13 | 5.21 | 49.74 | 18.95 | 0.43 | 0.83 |
| | 4 | 5/31/27 | Dry-seeds shattered | Merced Co. | 4.77 | 1.43 | 48.91 | 30.58 | 0.30 | 0.29 |
| | 5 | 10/3/27 | Dry-seeds shattered | Merced Co. | 5.07 | 1.56 | 55.95 | 24.98 | 0.32 | 0.30 |
| | 6* | 4/25/21 | Green-beards soft | Shingle Springs | 5.54 | 1.79 | 56.84 | 26.56 | 0.72 | 0.64 |
| Bur clover | 7 | 3/28/27 | Green | Merced Co. | 25.37 | 4.03 | 46.69 | 13.85 | 1.28 | 0.86 |
| | 8 | 5/31/27 | Mature-dry | Merced Co. | 18.31 | 1.85 | 49.69 | 21.59 | 1.36 | 0.55 |
| | 9 | 10/3/27 | Mature—dry | Merced Co. | 16.38 | 2.66 | 49.50 | 23.85 | 1.54 | 0.60 |
| Giant brome | 10* | 3/29/21 | Beginning to bloom | Berkeley | 13.44 | 2.06 | 45.18 | 29.44 | | |
| | 11 | 4/25/21 | Beginning to bloom | Shingle Springs | 7.94 | 2.70 | 48.79 | 29.16 | 0.71 | 0.99 |
| | 12 | 5/6/21 | Partly dry | Berkeley | 8.00 | 1.83 | 54.80 | 27.87 | 0.50 | 0.86 |
| | 13 | 6/30/21 | Mature—seeds dropped | Berkeley | 5.95 | 2.02 | 49.07 | 35.12 | | |
| | 14 | 9/22/21 | Mature—seeds dropped | Berkeley | 4.67 | 1.82 | 50.61 | 36.41 | 0.55 | 0.41 |
| Soft chess or cheat | 15 | 4/25/21 | Green—full bloom | Shingle Springs | 7.06 | 1.75 | 53.52 | 28.67 | | |
| | 16* | 8/10/21 | Dry | Shingle Springs | 4.50 | 0.93 | 46.20 | 40.00 | 0.49 | 0.63 |
| | 17 | 10/10/21 | Dry | Shingle Springs | 4.00 | 1.21 | 53.26 | 35.13 | 0.58 | 0.67 |
| | 18 | 1/6/21 | Old feed—exposed to rain | Shingle Springs | 4.01 | 0.61 | 50.00 | 41.31 | | |
| Wild oats | 19* | 8/10/21 | Dry | Shingle Springs | 5.91 | 1.55 | 45.55 | 38.73 | 0.39 | 0.79 |
| | 20 | 8/10/21 | Dry | Berkeley | 2.31 | 2.05 | 54.23 | 35.94 | 0.22 | 0.48 |
| Italian rye | 21 | 3/29/21 | Before bloom | Berkeley | 13.65 | 3.77 | 53.64 | 18.05 | | |
| | 22* | 5/6/21 | Heading out | Berkeley | 12.38 | 3.81 | 52.07 | 22.82 | 0.62 | 0.61 |
| | 23 | 6/30/21 | Mature—leaves green | Berkeley | 7.74 | 2.86 | 50.99 | 28.89 | 0.74 | 0.50 |
| | 24 | 9/22/21 | Dry—seeds dropped | Berkeley | 3.02 | 2.90 | 43.65 | 43.89 | 0.41 | 0.32 |

* These samples collected in 1921 by Woll, Kennedy and Jaffa in a study of nutritive value of forage plants on California ranges. Analysis made and data presented by H. Goss.

In the next group of analyses, on foxtail, sample No. 3 cut in the early stage was high in protein, low in fiber and high in phosphorus. The amount of protein is approximately 3½ times as great as in samples 4 and 5, cut when fully mature and dry. A similar drop is found in the phosphorus. The fat decreases and the fiber increases. With this increase in fiber the digestibility rapidly decreases. The most significant difference between the feed, when most relished by livestock and when it is clearly recognized as poor feed, is in the protein and phosphorus content. The change from a succulent to a dry fibrous feed of course markedly affects palatability and digestibility.

The same trend in lower protein and ash content is found in the other grasses. It should be noted that the calcium content of the grasses from Shingle Springs in the Sierra Nevada foothills and from Berkeley is higher than in those from Merced County. The phosphorus content of the dry grasses was also higher than in the Merced samples. The calcium content of foxtail collected at Shingle Springs, for example, is about 60 per cent higher than that found at any time in samples from the Merced range.

The third group of analyses on bur clover from the Merced County range constituting samples 7, 8 and 9, show a high protein and ash content throughout the season, and indicate the reason for the high value placed upon this feed by stockmen. It is significant to again observe that the most striking difference in the chemical composition of this good feed and the poor feeds is in the protein and ash constituents. The lower fiber content of the dry bur clover, as compared to the dry grasses, is another factor in its favor, but this difference is not nearly so great as in the protein and minerals.

The analyses of giant brome grass—samples 10 to 14—taken from Berkeley and Shingle Springs, show the same trend of decrease in protein and ash with increase in fiber when the plants cure. The calcium and phosphorus content is somewhat higher, however, than that in the Merced grasses.

The series of analyses on soft chess or cheat—samples 15 to 18—are interesting in that sample 18 had been exposed all summer and to numerous rains in the fall. It is generally recognized that a rain, after the forage drys, spoils the feed. A comparison of this forage with samples 16 and 17, collected in August and October and not exposed to rain, shows very little change in amount of protein, a decrease in the already small quantity of fat, a slight decrease in the nitrogen-free extract and a small increase in fiber. Unfortunately analyses for calcium and phosphorus are not available, but the total ash (not given in the table) decreased from 8.26 per cent in August to 4.10 per cent in January.

It is obvious that dry range grasses are deficient in protein, and the first consideration of the stockman who is desirous of maintaining his cow herd in the strong condition necessary for efficient reproduction should consist in making good this deficiency. Cottonseed cake will meet this requirement and is also high in phosphorus, but with its increasing demand other high protein feeds may become more economical.

When cattle are confined to dried grasses, such as wild oats, bromes, etc., about 2 pounds of cottonseed cake daily will be necessary to furnish an adequate supply of protein for a 1,000 pound animal, although a smaller quantity will be decidedly beneficial.

From the results of the digestion trial by Mead and Guilbert previously mentioned, table 5 is presented showing the requirements of a 1,000 pound beef cow in calf, the amount of nutrients supplied by the dry range grass used in the trial and how the deficiency in protein is met by cottonseed meal. The nutritive requirements given in the table are calculated to allow for some gain in weight.

TABLE 5

REQUIREMENTS OF A 1,000 POUND BEEF COW IN CALF (MORRISON STANDARDS) AND AMOUNT OF NUTRIENTS FURNISHED BY 25 POUNDS OF DRY RANGE GRASS AND 2 POUNDS OF COTTONSEED CAKE

| | Protein, pounds | Total digestible nutrients, pounds |
|---|---|---|
| Requirement of a 1,000-pound beef cow in calf | 0.7–0.9 | 9.0–12.0 |
| Amount furnished by 25 pounds of dry range grass | None | 11.11 |
| 2 pounds of 41% protein cottonseed cake | 0.74 | 1.56 |
| Total | 0.74 | 12.67 |

The figures in the table indicate that if the cow can obtain 25 pounds of the grass daily the energy requirement for maintenance will be met but she will get little or no protein. The two pounds of cottonseed cake will meet the minimum protein requirement and, besides, furnish additional energy for gain in weight.

The most desirable method for feeding supplemental concentrates on the range is to feed the cattle wherever they happen to be grazing, as cattle fed in this way are less disturbed and spend less time away from grazing than if they are fed in a central place. Moreover, better distribution of cattle on the range is maintained and less time is spent in traveling over areas where feed is depleted. On very poor quality roughage, feeding of small quantities of concentrate may have a slight tendency to decrease the amount of range forage consumed. However,

the amount of the concentrate fed is so small that it is not reasonable to believe that it would affect the appetite materially, and very good evidence is available showing increase in feed consumption where the ration is well balanced, compared to a deficient ration. Limited hay feeding on the other hand more nearly satisfies the animal's desire for bulk and probably has a greater effect on cutting down the "rustling" tendencies of the stock, consequently the utilization of range feed. When cake is fed on the ground it will pay to screen out the fine material, which results in saving 5–15 per cent of this material for feeding in troughs. The most efficient results from supplementary feeding come from supplying the nutrients which are most lacking in the range forage.

Bone meal can be fed in troughs in the same manner as salt is commonly given. High grade steamed bone meal which is finely ground should be used. The appetite of the animal is the best index at present available as to whether or not additional calcium or phosphorus is needed, both of which are supplied by bone meal.

From the foregoing general discussion, it must be recognized that a great deal more investigational work will be necessary to ascertain the areas in California on which natural feeds during a part or all of the year may be lacking in essential dietary factors. There is great need for a method by which an examination of blood, milk, or some other body fluid would give information on the stage of mineral metabolism in a group of animals. The actual mineral and other nutritive content of the most important range grasses in various parts of the state over a series of years is needed. With this knowledge, the employment of supplemental feed could be carried out more effectively and profitably. It must be recognized that conditions in a single locality vary from year to year, depending on climatic conditions. Considerable capital outlay for supplemental feed may be necessary one year, with practically none on another year. Many of these conditions would be automatically met if ranges were stocked with no greater number of cattle than could be carried through in good condition in poor years. Where it is economically necessary to stock ranges to capacity on good years, meeting the adverse conditions on poor years is essential.

## SUMMARY

1. Cost of production studies have shown that the percentage calf crop is a very important factor in economical beef production.

2. Various factors have long been recognized as influencing the calf crop among which may be mentioned:

The plane of nutrition of the animals.

The season of breeding.

The proportion of males to females.

The distribution of males and females on the range.

Bovine infectious abortion.

Selection of breeding stock by proper culling.

3. Evidence is presented to show that failure to conceive is a more important factor than abortion, in the range area.

4. Failure to conceive has been shown to be often due to the existence of a faulty plane of nutrition resulting in a lack of proper functioning of the ovary and no manifestation of heat periods. It has been observed in cattle in various parts of the world. Evidence of a similar character has been observed in wild animals in their native habitats.

5. A suboptimum plane of nutrition in bulls may result in reduced breeding activity or fertility, or both.

6. Evidence during the past few years has accumulated showing that failure to conceive is at least in part due to restricted mineral intake with the food, particularly involving calcium and phosphorus.

7. It is also recognized that a deficiency of minerals under range conditions is associated with low protein intake.

8. In general low mineral content of feed is associated with deficient soil content of the same mineral elements.

9. The extent of the manifestation of deficiency depends on climatic conditions which vary the length of time the animals are on dry feed.

10. Cows that have weaned calves in the fall and are again pregnant must usually gain during the early winter season if they are to be at a normal weight by the next calving time. Frequently they have poor feed at this time and lose weight.

11. While bone craving and other forms of depraved appetite are evidences of advanced stages of nutritional deficiency the animal may be in a suboptimum stage of nutrition without showing these symptoms.

12. The disturbed rhythmic functioning of the ovary is one of the most delicate evidences of impaired physiological function due to a lowered plane of nutrition. This is most likely to be manifested in seasons of drought, with prolonged maintenance on dry and sparse feed. Under these conditions mineral and protein supplements are most necessary to maintain the normal functions of the animals.

13. Bone meal offers the most desirable mineral supplement, and from present knowledge the appetite of the animal for this material offers the best available index of need for it.

14. Any protein concentrate such as cottonseed cake that is economically available may be used to supplement the range feed. The principal difference between good and poor range feed is in the mineral and protein content.

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